

What is Claimed is:

1. An electromagnetic flowmeter comprising:
 - 2 a measuring pipe through which a fluid to be
 - 3 measured flows;
 - 4 an electrode which is arranged in said
 - 5 measuring pipe and detects an electromotive force
 - 6 generated by a magnetic field applied to the fluid and
 - 7 flow of the fluid;
 - 8 a first exciting coil which is arranged
 - 9 separately from a plane, which includes said electrode
 - 10 and is perpendicular to a direction of an axis of said
 - 11 measuring pipe, and applies a first magnetic field
 - 12 having a first frequency to the fluid;
 - 13 a second exciting coil which is arranged on a
 - 14 side opposite to said first exciting coil with respect
 - 15 to the plane and applies, to the fluid, a second
 - 16 magnetic field obtained by amplitude-modulating a
 - 17 carrier having the first frequency by a modulated wave
 - 18 having a second frequency;
 - 19 a power supply section which supplies an
 - 20 exciting current to said first exciting coil and said
 - 21 second exciting coil;
 - 22 a signal conversion section which separates a
 - 23 component of the first frequency from the electromotive
 - 24 force detected by said electrode to obtain an amplitude,
 - 25 separates one of components of sum and difference

26 frequencies of the first and second frequencies from the
27 electromotive force to obtain an amplitude, and obtains
28 a ratio of the amplitudes; and
29 a flow rate output section which calculates a
30 flow rate of the fluid on the basis of the amplitude
31 ratio obtained by said signal conversion section.

2. A flowmeter according to claim 1, wherein
2 on the basis of the amplitude ratio R_{am}
3 obtained by said signal conversion section, a phase
4 difference $\theta 2$ between the carrier components of the
5 first and second magnetic fields, and an amplitude
6 modulation index m_a of the second magnetic field, said
7 flow rate output section calculates the flow rate of the
8 fluid by $\alpha \times \omega 0 \{-8 \sin(\theta 2) + R_{am} m_a (16 - R_{am}^2 m_a^2)^{1/2}\} / \{8 +$
9 $8 \cos(\theta 2) - R_{am}^2 m_a^2\}$ (α is a coefficient).

3. An electromagnetic flowmeter comprising:
2 a measuring pipe through which a fluid to be
3 measured flows;
4 an electrode which is arranged in said
5 measuring pipe and detects an electromotive force
6 generated by a magnetic field applied to the fluid and
7 flow of the fluid;
8 a first exciting coil which is arranged
9 separately from a plane, which includes said electrode
10 and is perpendicular to a direction of an axis of said

11 measuring pipe, and applies a first magnetic field
12 having a first frequency to the fluid;
13 a second exciting coil which is arranged on a
14 side opposite to said first exciting coil with respect
15 to the plane and applies, to the fluid, a second
16 magnetic field obtained by amplitude-modulating a
17 carrier having the first frequency by a modulated wave
18 having a second frequency;
19 a power supply section which supplies an
20 exciting current to said first exciting coil and said
21 second exciting coil;
22 a signal conversion section which separates a
23 component of the first frequency from the electromotive
24 force detected by said electrode to obtain a first phase
25 difference between the first exciting current supplied
26 to said first exciting coil and the component of the
27 first frequency separated from the electromotive force,
28 and separates one of components of sum and difference
29 frequencies of the first and second frequencies from the
30 second exciting current supplied to said second exciting
31 coil and separates one of the components of the sum and
32 difference frequencies from the electromotive force to
33 obtain a second phase difference for the same frequency
34 between the component separated from the second exciting
35 current and the component separated from the
36 electromotive force; and
37 a flow rate output section which calculates a

38 flow rate of the fluid on the basis of the first phase
39 difference and the second phase difference obtained by
40 said signal conversion section.

4. A flowmeter according to claim 3, wherein
2 on the basis of the first phase difference ϕ
3 or and the second phase difference ϕ_{am} , which are
4 obtained by said signal conversion section, the first
5 frequency ω_0 , and a phase difference θ_2 between the
6 carrier components of the first and second magnetic
7 fields, said flow rate output section calculates the
8 flow rate of the fluid by $\alpha \times \omega_0 \tan(\pi/2 + \phi_{am} - \phi$
9 or $- \theta_2/2)$ (α is a coefficient).

5. An electromagnetic flowmeter comprising:
2 a measuring pipe through which a fluid to be
3 measured flows;
4 an electrode which is arranged in said
5 measuring pipe and detects an electromotive force
6 generated by a magnetic field applied to the fluid and
7 flow of the fluid;
8 a first exciting coil which is arranged
9 separately from a plane, which includes said electrode
10 and is perpendicular to a direction of an axis of said
11 measuring pipe, and applies, to the fluid, a first
12 magnetic field obtained by amplitude-modulating a
13 carrier having a first frequency by a modulated wave

14 having a second frequency;
15 a second exciting coil which is arranged on a
16 side opposite to said first exciting coil with respect
17 to the plane and applies, to the fluid, a second
18 magnetic field obtained by amplitude-modulating the
19 carrier having the first frequency by a modulated wave
20 having the same frequency as that of the modulated wave
21 and an opposite phase;
22 a power supply section which supplies an
23 exciting current to said first exciting coil and said
24 second exciting coil;
25 a signal conversion section which separates a
26 component of the first frequency from the electromotive
27 force detected by said electrode to obtain an amplitude,
28 separates one of components of sum and difference
29 frequencies of the first and second frequencies from the
30 electromotive force to obtain an amplitude, and obtains
31 a ratio of the amplitudes; and
32 a flow rate output section which calculates a
33 flow rate of the fluid on the basis of the amplitude
34 ratio obtained by said signal conversion section.

6. A flowmeter according to claim 5, wherein
2 on the basis of the amplitude ratio R_{am}
3 obtained by said signal conversion section, a phase
4 difference θ_2 between the carrier components of the
5 first and second magnetic fields, and an amplitude

6 modulation index m_a of the first and second magnetic
7 fields, said flow rate output section calculates the
8 flow rate of the fluid by $\alpha \times \omega_0 \{ R m_a \cos(\theta$
9 $2/2) - 2 \sin(\theta 2/2) \} / \{ R m_a \sin(\theta 2/2) + 2 \cos(\theta 2/2) \}$ (α is
10 a coefficient).

7. An electromagnetic flowmeter comprising:
2 a measuring pipe through which a fluid to be
3 measured flows;
4 an electrode which is arranged in said
5 measuring pipe and detects an electromotive force
6 generated by a magnetic field applied to the fluid and
7 flow of the fluid;
8 a first exciting coil which is arranged
9 separately from a plane, which includes said electrode
10 and is perpendicular to a direction of an axis of said
11 measuring pipe, and applies a first magnetic field
12 having a first frequency to the fluid;
13 a second exciting coil which is arranged on a
14 side opposite to said first exciting coil with respect
15 to the plane and applies, to the fluid, a second
16 magnetic field obtained by phase-modulating a carrier
17 having the first frequency by a modulated wave having a
18 second frequency;
19 a power supply section which supplies an
20 exciting current to said first exciting coil and said
21 second exciting coil;

22 a signal conversion section which, when a
 23 frequency corresponding to an integer multiple of the
 24 second frequency is defined as a third frequency,
 25 separates a component of the first frequency from the
 26 electromotive force detected by said electrode to obtain
 27 an amplitude, separates one of components of sum and
 28 difference frequencies of the first and third
 29 frequencies from the electromotive force to obtain an
 30 amplitude, and obtains a ratio of the amplitudes; and
 31 a flow rate output section which calculates a
 32 flow rate of the fluid on the basis of the amplitude
 33 ratio obtained by said signal conversion section.

8. A flowmeter according to claim 7, wherein
 2 on the basis of the amplitude ratio R_{pm}
 3 obtained by said signal conversion section, the first
 4 frequency ω_0 , a phase difference θ_2 between the
 5 carrier components of the first and second magnetic
 6 fields, a phase modulation index m_p of the second
 7 magnetic field, and a Bessel function of fractional
 8 order $J_n(m_p)$ ($n = 0$ or 1), said flow rate output section
 9 calculates the flow rate of the fluid by $\alpha \times [\omega$
 10 $0\{-2J_0(m_p)\sin(\theta_2) + \{2J_0(m_p)^2 - J_0(m_p)^4 +$
 11 $2J_0(m_p)^2 J_1(m_p)^2 R_{pm}^2 - 1 + 2J_1(m_p)^2 R_{pm}^2 - J_1(m_p)^4 R_{pm}^4\}^{1/2}\}]/\{J_0(m_p)^2$
 12 $+ 1 + 2J_0(m_p)\cos(\theta_2) - J_1(m_p)^2 R_{pm}^2\}$ (α is a coefficient).

9. An electromagnetic flowmeter comprising:

2 a measuring pipe through which a fluid to be
3 measured flows;

4 an electrode which is arranged in said
5 measuring pipe and detects an electromotive force
6 generated by a magnetic field applied to the fluid and
7 flow of the fluid;

8 a first exciting coil which is arranged
9 separately from a plane, which includes said electrode
10 and is perpendicular to a direction of an axis of said
11 measuring pipe, and applies, to the fluid, a first
12 magnetic field obtained by phase-modulating a carrier
13 having a first frequency by a modulated wave having a
14 second frequency;

15 a second exciting coil which is arranged on a
16 side opposite to said first exciting coil with respect
17 to the plane and applies, to the fluid, a second
18 magnetic field obtained by phase-modulating the carrier
19 having the first frequency by a modulated wave having
20 the same frequency as that of the modulated wave and an
21 opposite phase;

22 a power supply section which supplies an
23 exciting current to said first exciting coil and said
24 second exciting coil;

25 a signal conversion section which, when a
26 frequency corresponding to an integer multiple of the
27 second frequency is defined as a third frequency,
28 separates a component of the first frequency from the

29 electromotive force detected by said electrode to obtain
 30 an amplitude, separates one of components of sum and
 31 difference frequencies of the first and third
 32 frequencies from the electromotive force to obtain an
 33 amplitude, and obtains a ratio of the amplitudes; and
 34 a flow rate output section which calculates a
 35 flow rate of the fluid on the basis of the amplitude
 36 ratio obtained by said signal conversion section.

10. A flowmeter according to claim 9, wherein
 2 on the basis of the amplitude ratio R_{pm}
 3 obtained by said signal conversion section, the first
 4 frequency ω_0 , a phase difference θ_2 between the
 5 carrier components of the first and second magnetic
 6 fields, a phase modulation index m_p of the first and
 7 second magnetic fields, and a Bessel function of
 8 fractional order $j_n(m_p)$ ($n = 0$ or 1), said flow rate
 9 output section calculates the flow rate of the fluid by
 10 $\alpha \times \omega_0 [-\{J_0(m_p)^2 \cos(\theta_2) \sin(\theta_2) + J_1(m_p)^2 \sin(\theta_2) \cos(\theta_2)\} R_{pm}^2 + J_1(m_p)^2 \sin(\theta_2) R_{pm}^2 + J_0(m_p)^2 \sin(\theta_2)] +$
 11 $2 [J_0(m_p) J_1(m_p) \{ \cos(\theta_2) + 1 \} R_{pm}] / \{ 2 J_0(m_p)^2 \cos(\theta_2) + J_0(m_p)^2$
 12 $+ J_0(m_p)^2 \cos(\theta_2)^2 - J_1(m_p)^2 R_{pm}^2 + J_1(m_p)^2 \cos(\theta_2)^2 R_{pm}^2 \}$ (α is
 13 a coefficient).
 14

11. An electromagnetic flowmeter comprising:
 2 a measuring pipe through which a fluid to be
 3 measured flows;

4 an electrode which is arranged in said
5 measuring pipe and detects an electromotive force
6 generated by a magnetic field applied to the fluid and
7 flow of the fluid;
8 a first exciting coil which is arranged
9 separately from a plane, which includes said electrode
10 and is perpendicular to a direction of an axis of said
11 measuring pipe, and applies a first magnetic field
12 having a first frequency to the fluid;
13 a second exciting coil which is arranged on a
14 side opposite to said first exciting coil with respect
15 to the plane and applies, to the fluid, a second
16 magnetic field obtained by frequency-modulating a
17 carrier having the first frequency by a modulated wave
18 having a second frequency;
19 a power supply section which supplies an
20 exciting current to said first exciting coil and said
21 second exciting coil;
22 a signal conversion section which, when a
23 frequency corresponding to an integer multiple of the
24 second frequency is defined as a third frequency,
25 separates a component of the first frequency from the
26 electromotive force detected by said electrode to obtain
27 an amplitude, separates one of components of sum and
28 difference frequencies of the first and third
29 frequencies from the electromotive force to obtain an
30 amplitude, and obtains a ratio of the amplitudes; and

31 a flow rate output section which calculates a
 32 flow rate of the fluid on the basis of the amplitude
 33 ratio obtained by said signal conversion section.

12. A flowmeter according to claim 11, wherein
 2 on the basis of the amplitude ratio R_{fm}
 3 obtained by said signal conversion section, the first
 4 frequency ω_0 , a phase difference θ_2 between the
 5 carrier components of the first and second magnetic
 6 fields, a frequency modulation index m_f of the second
 7 magnetic field, and a Bessel function of fractional
 8 order $J_n(m_f)$ ($n = 0$ or 1), said flow rate output section
 9 calculates the flow rate of the fluid by $\alpha \times [\omega$
 10 $0\{-2J_0(m_f)\sin(\theta_2) + \{2J_0(m_f)^2 - J_0(m_f)^4 +$
 11 $2J_0(m_f)^2 J_1(m_f)^2 R_{fm}^2 - 1 + 2J_1(m_f)^2 R_{fm}^2 - J_1(m_f)^4 R_{fm}^4\}^{1/2}\}]/\{J_0(m_f)^2$
 12 $+ 1 + 2J_0(m_f)\cos(\theta_2) - J_1(m_f)^2 R_{fm}^2\}$ (α is a coefficient).

13. An electromagnetic flowmeter comprising:
 2 a measuring pipe through which a fluid to be
 3 measured flows;
 4 an electrode which is arranged in said
 5 measuring pipe and detects an electromotive force
 6 generated by a magnetic field applied to the fluid and
 7 flow of the fluid;
 8 a first exciting coil which is arranged
 9 separately from a plane, which includes said electrode
 10 and is perpendicular to a direction of an axis of said

11 measuring pipe, and applies, to the fluid, a first
12 magnetic field obtained by frequency-modulating a
13 carrier having a first frequency by a modulated wave
14 having a second frequency;
15 a second exciting coil which is arranged on a
16 side opposite to said first exciting coil with respect
17 to the plane and applies, to the fluid, a second
18 magnetic field obtained by frequency-modulating the
19 carrier having the first frequency by a modulated wave
20 having the same frequency as that of the modulated wave
21 and an opposite phase;
22 a power supply section which supplies an
23 exciting current to said first exciting coil and said
24 second exciting coil;
25 a signal conversion section which, when a
26 frequency corresponding to an integer multiple of the
27 second frequency is defined as a third frequency,
28 separates a component of the first frequency from the
29 electromotive force detected by said electrode to obtain
30 an amplitude, separates one of components of sum and
31 difference frequencies of the first and third
32 frequencies from the electromotive force to obtain an
33 amplitude, and obtains a ratio of the amplitudes; and
34 a flow rate output section which calculates a
35 flow rate of the fluid on the basis of the amplitude
36 ratio obtained by said signal conversion section.

14. A flowmeter according to claim 13, wherein

2 on the basis of the amplitude ratio R_{fm}

3 obtained by said signal conversion section, the first

4 frequency ω_0 , a phase difference θ_2 between the

5 carrier components of the first and second magnetic

6 fields, a frequency modulation index m_f of the first and

7 second magnetic fields, and a Bessel function of

8 fractional order $j_n(m_f)$ ($n = 0$ or 1), said flow rate

9 output section calculates the flow rate of the fluid by

10 $\alpha \times \omega_0 [-\{J_0(m_f)^2 \cos(\theta_2) \sin(\theta_2) + J_1(m_f)^2 \sin(\theta_2) \cos(\theta_2)\} R_{fm}^2 + J_1(m_f)^2 \sin(\theta_2) R_{fm}^2 + J_0(m_f)^2 \sin(\theta_2)] +$

11 $2 |J_0(m_f) J_1(m_f) \{ \cos(\theta_2) + 1 \} R_{fm}| / \{ 2 J_0(m_f)^2 \cos(\theta_2) + J_0(m_f)^2$

12 $+ J_0(m_f)^2 \cos(\theta_2)^2 - J_1(m_f)^2 R_{fm}^2 + J_1(m_f)^2 \cos(\theta_2)^2 R_{fm}^2 \}$ (α is

13 a coefficient).